Hourglass

Preface

See the User's Manual (*HOURGLASS) and sections 3.2 and 6.4 of the Theory Manual.

Hourglass (HG) modes are nonphysical, zero-energy modes of deformation that produce zero strain and no stress. Hourglass modes occur only in under-intetgrated (single integration point) solid, shell, and thick shell elements. LS-DYNA has various algorithms for inhibiting hourglass modes. The default algorithm (type 1), while the cheapest, is generally not the most effective algorithm.

A way to entirely eliminate hourglass concerns is to switch to element formulations with fully-integrated or selectively reduced (S/R) integration. There can be a downside to this approach. For example, type 2 solids are much more expensive than the single point default solid. Secondly, they are much more unstable in large deformation applications (negative volumes much more likely). Third, type 2 solids have some tendency to 'shear-lock' and thus behave too stiffly in applications where the element shape is poor.

Notice

Triangular shells and tetrahedral solid elements do not have hourglassing modes but have drawbacks with regard to overly stiff behavior in some applications.

A good way to reduce hourglassing is to refine your mesh.

The method of loading can affect the degree of hourglassing. A pressure loading is preferred over loading individual nodes as the latter approach is more likely to excite hourglassing modes.

To evaluate hourglass energy, set HGEN to 2 in *CONTROL_ENERGY and use *DATABASE_GLSTAT and *DATABASE_MATSUM to report the HG energy for the system and for each part, respectively. The point is to confirm that the nonphysical HG energy is small relative to peak internal energy for each part (<10% as a rule-of-thumb). For shells only, you can fringe hourglass energy density by first setting SHGE=2 in the LS-DYNA input deck (*DATABASE_EXTENT_BINARY). Then, in LS-Prepost, choose Fcomp >> Misc >> hourglass energy.

For fluid parts, the default HG coefficient is generally inappropriate (too high). Thus for fluids, the hourglass coefficient should generally be scaled back several orders of magnitude. Use only viscosity-based HG control for fluids. The default HG formulation (type 1) is generally ok for fluids. Please note that in 971 R3, the default hourglass coefficient for ALE parts (ELFORM 11) is 1.e-6. To override that default, as might be appropriate for non-fluid materials, use *HOURGLASS and HGID in *PART. Check the hourglass energy via MATSUM.

Hourglass types

Stiffness-based HG control (types 4,5) is generally more effective than viscous HG control for structural parts. Usually, when stiffness-based HG control is invoked, I like to reduce the HG coefficient, usually in the range of .03 to .05, soas to minimize nonphysical stiffening of the response and at the same time effectively inhibiting hourglass modes. For high velocity impacts, viscosity-based HG control (types 1,2,3) is recommended even for solid/structural parts.

`Type 8 HG` control applies only to shell formulation 16. This `HG` type activates warping stiffness in type 16 shells so that warping of the element does not degrade the solution. Type 16 shells will solve the so-called Twisted Beam problem correctly if `HG type 8` is invoked.

`Type 6 HG` control invokes an assumed-strain co-rotational formulation for type 1 solid elements and under-integrated 2D solids (shell types 13 and 15). With the `HG` type set to 6 and the hourglass coefficient set to 1.0, an elastic part need only be modeled with a single type 1 solid through its thickness to achieve the exact bending stiffness. `Type 6 HG` control should always be used for type 1 solids in implicit simulations (in fact, this is done automatically in v. 970).

The hourglass coefficient for `type 6 HG` control will typically range from 0.1 (default) to 1.0. For elastic material, use 1.0. For other materials, the choice of `HG` coefficient is not obvious. Even looking at results, it may be difficult to quantify the 'goodness' of the hourglass coefficient used. Too low a value may result in visible hourglass modes of deformation (unlikely). Too high a value may result in overly stiff behavior. It may be necessary to run the model twice to see if the results exhibit any sensitivity to the hourglass coefficient. Checking the hourglass energy is a good idea.

The default hourglass coefficient of 0.1 is superseded by any nonzero value given for `QH` in `*CONTROL_HOURGLASS`. I see nothing in the manual to contradict this interpretation. The manual does say that the default hourglass type in `*HOURGLASS` is 1 regardless of what's given in `*CONTROL_HOURGLASS`. Unless I missed something, no such note appears with regard to hourglass coefficient. The lesson here is that users should specify a nonzero hourglass coefficient wherever `*HOURGLASS` is used. Otherwise, the user may, as you did, inadvertently change the intended coefficient by use of `*CONTROL_HOURGLASS`.